**Cheap Clean**

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Expensive technology, even if it yields clean energy, cannot solve the challenge of global warming. Any solution, to be viable, must be low enough in cost that the world can afford to implement it widely. Indeed, it is likely that the only technologies that are sustainable are those that are beyond cheap – those that are profitable.   The reason for this conclusion is a key fact that underlies the IPCC projections of global warming: the predicted rise in temperature is tightly linked to the end of poverty in the developing world.   Economic progress in the developing world has been amazing and exciting. Growth of the GDP of China and India has set a pace of 6% to 12% per year, an improvement that is cheered by every caring person. But that growth has been accompanied by a matching increase in energy use. The correlation is not accidental; wealth is tightly linked to energy. To find the GDP of any country, take the yearly total energy use per capita in kilowatt-hours (all energy, not just electricity) and divide by 3. That gives the GDP per capita in USD, within a factor of two, for virtually all the countries in the world.   True, the developed world has been responsible for most of the observed 0.5 C global warming so far. But that is changing. China already releases more greenhouse gas each year than the US. In fact, the preponderance of the expected future warming will arise from the economic rise of the developing world. Expensive technologies that can be used by wealthy nations to reduce emissions are not a viable option for the poorer nations, until they too are wealthy – but by then, it will likely be too late.   There is no blame in this. The developing world has the right to the same standard of living as the developed world. A leader of a developing nation may very likely be more concerned about poverty, poor nutrition and health, inadequate education and lack of opportunity, than about a few degrees temperature rise.   It is not good enough for the developed world to "set an example" if the approach is too expensive for the developing world to afford.   Not only must we reduce greenhouse emissions, we must do that in a sustainable way, a way that will continue to work during economic turndowns. The one clear way to achieve that goal is to emphasize reductions which are profitable. Sustainability and profitability are inextricably linked.   Using these observations for guidance, the possible solutions are as follows:   1. Improve energy efficiency. Developing nations are extremely inefficient in their energy use. This was true for the United States in the 19th and 20th centuries, and is true of China and India now. The carbon dioxide of these nations per GDP is 3 to 5 times greater than in the US. We need to help the developing world achieve higher efficiency on a quicker time schedule.   2. Improve energy conservation. As verified by the McKinsey study, using conservation to reduce carbon emissions can be profitable with remarkably short pay-back times. Heating and air conditioning can be reduced by using better insulation and IR reflecting roofs. Cooking and lighting can use much less fuel. These measures are readily adaptable in the developing world, and can yield virtually immediate economic benefits.   3. Search for clean tech solutions that are cheaper than the dirty ones. The biggest challenge: provide energy cheaper than we can get from coal. In my estimation, some of the technologies that offer this possibility are wind, thin-film solar, and small-scale nuclear. Not likely in my opinion: geothermal (in most of the world); large-scale solar thermal; wave or tidal power.   4. Develop technology that addresses not only clean energy, but also energy security. Energy security is highly valued in many countries, so technology that addresses this need can find a market even if it is not as cheap as, say, imported natural gas. The technologies are very location specific, and could include biofuels, wind, and solar.   5. Develop carbon capture and sequestration as a back-up in case coal remains the cheapest form of energy. The technology must be such that it can be used in the developing world, perhaps subsidized by the wealthier nations.   6. Electric autos in the developing world, where expectations of long driving range are not yet part of their culture. The emphasis must be on cheap batteries, since replacement costs are the greatest expense.   7. In exchange for carbon reductions among the developed nations, the poorer nations must agree to allow foreign technology be used to help them reduce their own emissions. This could be everything from advanced wind turbines, better solar cells, small nuclear plants, to carbon sequestration technology. Many developing nations want to create their own technology, and may put up barriers to use of foreign methods. But if this happens, the cheap tech may never be developed. The huge markets in the developing world are the best inspiration for the huge investments that will be needed to make clean cheap.   Some people advocate cap and trade as a solution. But the real value of cap and trade is reached only if it inspires the development of inexpensive clean energy technologies. Unless clean becomes cheap, it will not be adopted by the developing world, and without that, atmospheric carbon dioxide increases are inevitable.   Expensive clean won’t work. Cheap clean is essential. To be sustainable, clean technology must be profitable. The best bets: energy efficiency and conservation.